Submarine Warfare 3.0: A Combat Systems Evolution – The new Domains of Submarine Warfare

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14. ABSTRACT

With the rise of Near Peer military competition, submarine warfare must evolve into new warfare domains and establish a new infrastructure to support the payloads of the future rapidly and securely. Submarines have evolved over the past 100 years from simple fleet reconnaissance platforms to blockade enforcing weapons to stealth missile deployment systems. This advancement has established the submarine as the essential naval platform for any conflict starting with World War I and continuing through the Global War on Terror (GWOT). The evolution of submarine technology over the past century has been continual and cutting edge, and now must advance again to meet the challenge of Near Peer competition.

In the recent era of global warfare, the attack submarine's primary mission and value to the U.S. Navy has been as a guard for the Aircraft Carrier-centered Surface Action Groups (SAGs) and as an offensive weapon against an enemy's SAG. The growth of Near Peer competitors' standoff capability has now pushed the Navy SAGs outside of range of most traditional offensive capabilities. This standoff capability now gives a new objective and new domain to the submarine, which is multi-mission engagement and the platform for the opening shots of our next conflict. The key to the next phase of submarine warfare is a rapid flexible and secure combat infrastructure for new payloads.

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Introduction

With the rise of Near Peer military competition, submarine warfare must evolve into new warfare domains and establish a new infrastructure to support the payloads of the future rapidly and securely. Submarines have evolved over the past 100 years from simple fleet reconnaissance platforms to blockade enforcing weapons to stealth missile deployment systems. This advancement has established the submarine as the essential naval platform for any conflict starting with World War I and continuing through the Global War on Terror (GWOT). The evolution of submarine technology over the past century has been continual and cutting edge, and now must advance again to meet the challenge of Near Peer competition.

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In order to achieve this new combat infrastructure, the submarine must fundamentally change, and its traditional processes and architecture must change along with it. The U.S. submarine force has historically been cutting edge, yet it has been forced to evolve on many occasions responding to new warfare environments and hard lessons learned during operations. This is evidenced generationally in the submarine force, for example with the tragedy of the U.S.S. Thresher, the loss of acoustic superiority during the Cold War, and with the lack of rapidly flexible and secure combat capability today. Yet the submarine force has rapidly responded to these wake up calls. The Thresher disaster brought on the SUBSAFE program, and the sudden loss of acoustic superiority resulted in the Acoustic Rapid Capability Insertion (ARCI) program. Now is the time for the submarine force to once again adapt to changing conditions and move into a new generation of submarine warfare architecture.

The next major conflict will require a stealth undersea platform to deploy a wide range of payloads and do so securely in response to cyber threats. A heavy reliance on information systems creates a heavy attack surface for a cyber intrusion to render cutting edge submarine capability useless. The combat capability the submarine employs must be resilient against the robust cyber-attack capabilities of our Near Peer competitors. Developing this kind of rapid, flexible, and secure architecture will involve a new paradigm of submarine combat systems that employs rapid and flexible capability and security. A Modular Open System Architecture

(MOSA)[1] that would allow rapid incremental capability to be employed is key to this new era of submarine combat system.

Submarine Warfare 1.0: The First Evolution of Submarine Warfare

The submarine as a leading edge platform for every major era in Naval warfare can be traced back to its mission expansion from a reconnaissance platform in World War I to a powerful anti-ship weapon in World War II. At the onset of this era, the submarine was seen as a niche vessel only able to provide early warning capability for the main battle groups centered on the Dreadnaught battleships. As World War I progressed, a new capability was soon discovered as the German U-Boats such as the one in Figure 1[2] evolved into a powerful and effective anti-ship threat against Allied shipping and warships.

FIGURE 1: GERMAN U-BOAT WWI

Although the U-Boats were not designed specifically for the anti-ship mission, they evolved rapidly to meet the warfighting threats of the day. A mere generation later the submarine's new mission was fully exploited in World War II for the Axis and the Allies, which resulted in shipping losses of over 1,000 vessels[3]. This game changing capability had serious warfare effects, especially in the Pacific Theater of World War II. The submarine force acknowledged its limitations as a reconnaissance platform, but it also began to recognize its unique capability to disrupt enemy shipping and close key Sea Lines of Communications (SLOC). This played a key role in ending the war against Japan.

Battle of Jutland and a glimpse of the future of Submarine Warfare 1.0

While the land battles were raging in France in during World War I, a lukewarm war between the Grand Fleet of the British Navy and the High Seas Fleet of the German Navy was also going on. The Grand Fleet had enjoyed superiority at sea for centuries and was enforcing a

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[1] (Nickolas H. Guertin, 2018)

[2] (DREADNAUGHTZ, 2018)

[3] (Timothy J Runyan, 1994)

crippling blockade on Imperial Germany, depriving the military and civilian populations of food and resources to continue the fight. A drawn out "Cat and Mouse" game ensued between the two fleets, with a mission to force a decisive maritime battle as Alfred Mahan[4] dictated. The inevitable confrontation occurred at the Battle of Jutland in 1916 as the fleets clashed. This resulted in a controversial and indecisive end, with losses on both sides.

During this historical confrontation, the U-Boat submarines were employed on their originally designed mission to serve as an early warning platform and enable the High Seas Command to maneuver superior positioning. The U-boats established a picket line in order to detect where the Grand Fleet was approaching. Because of multiple limitations and operational failures, the U-Boats had very little impact over the battle and did not enable the German Navy to realize the decisive victory it had sought. The failure of Jutland to establish freedom of navigation for the High Seas Fleet prevented the German Navy from conducting operations for the reminder of the conflict. This environment resulted in the first evolution of the submarine as the U-Boat was the only platform able to still conduct operations due to its stealth nature. Unrestricted submarine warfare ensued against Allied shipping and stealth attacks against British warships at port. This disrupted Allied operations and gave the first glimpse of what the submarine would be evolving to. A warfare gap emerged for the German Navy after Jutland, but the submarine force showed how it could respond rapidly to that gap with the emergence of submarine warfare 1.0.

Unrestricted Submarine Warfare and the submarine as a critical warfare platform

Building on the anti-ship capability employed in World War I, the Submarine Force expanded its advantage in World War II. The Submarine Force employed a deadly campaign in the Atlantic and Pacific Theaters. The German Navy immediately responded with a devastating U-Boat campaign in the Atlantic starting in 1941 resulting in crippling losses for Britain. The submarine outpunched its weight as the Wolf Packs hunted allied merchant shipping to the tune of over 2 Million tons by 1943[5]. After 1943, however, the Allies adopted new tactics, such as the formation of merchant convoys and new technology like sonar and cryptology to respond to the U-Boat threat. This new campaign essentially ended the U-Boats' effectiveness in the Atlantic and for the remainder of the war.

The American Navy took notice of the German successes, even after new anti-submarine tactics and technology began to contain the German Submarine threat. The U.S. used the German tactics in a relentless attack against Japanese shipping in the Pacific where U.S.

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[4] (Mahan, 1894)

[5] (Timothy J Runyan, 1994)

submarines blockaded numerous Japanese island outposts and SLOCs. This had a significant impact on the Japanese military's ability to conduct combat operations. Although the campaign was a success, the explosive growth of anti-submarine tactics and technology during World War II once again signaled that a new evolution would need to occur to maintain the undersea combat advantage, submarine warfare 2.0.

Submarine Warfare 2.0: Acoustic Superiority and the Advent of ARCI

The Cold War brought on a new age of submarine warfare where a new architecture and new concepts were required to adapt to the threat. This resulted in the Acoustic Rapid Capability Insertion (ARCI) program in the 1990's. The Cold War brought the submarine to the forefront of combat capability as the SSBN force assumed the key role of Strategic Deterrence. The Attack Submarine Force was able to conduct critical Intelligence, Surveillance, and Reconnaissance (ISR) roles as well as special operation missions and remain undetected. This new role led to a dramatic growth in anti-submarine technology on both sides of the Cold War from the 1960's onward to counter each other and to allow their own undersea force to enhance their submarines combat capabilities. As a backdrop to the submarine arms race that was raging between the Warsaw Pact and NATO, the commercial technology boom was also raging out of Silicon Valley. This resulted in far more Research and Development (R&D) in digital technology occurring commercially than by the Defense Departments for the first time in history.

Moore's Law[6] predicted in 1965, and proved accurate, that computer processing technology would double in capability every 18 months. With the digitization of combat systems, this meant that new warfare critical capability would be overcome by our Near Peer competitors if the new Commercial Off the Shelf (COTS) digital hardware was not adopted quickly. Traditional combat systems took more than a decade to develop and install on a submarine platform, and there was little to no commonality between different classes of submarines. For example, the BSY-2 Submarine Combat Control System took over eight years to develop for the three Seawolf Class Submarines[7]. To compound the problem of long development schedules, these combat systems were not easily upgraded to

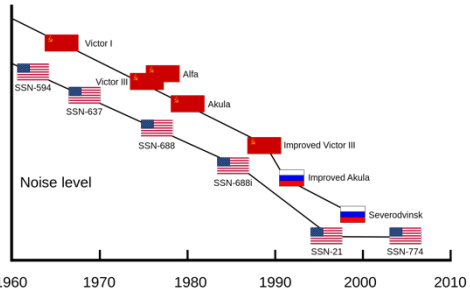

FIGURE 2: ACOUSTIC DEVELOPMENT OF THE COLD WAR

[6] (Moore, 1965)

[7] (Government Accountability Office (GAO), 1991)

the latest COTS hardware. This meant a brand new Submarine Combat System was using technology over a decade old and would not be able to be updated for at least another ten years. A new architecture and new philosophy was suddenly needed to respond to the rapid loss of acoustic superiority at sea, as seen in Figure 2[8]. The adversary's submarines were getting quieter and quieter, so new technology using superior computing processing needed to be implemented to detect lower and lower noise signatures.

To open the acoustic gap, the Submarine Force responded with the birth of ARCI. The ARCI program changed the philosophy of military combat system development from large monolithic closed off systems to a MOSA. This new program accepted the fact that the state of the practice COTS technology available when a system is delivered would exceed the capability of the state of the art technology when the system is being developed. ARCI was implemented with pre-planned and systematic hardware upgrades or Technical Insertions (TIs) and new combat software processing capability to take advantage of the improved hardware of the TIs called Advanced Processing Builds (APBs)[9] as shown in Figure 4[10]. ARCI in the 1990's and early 2000's brought a whole new age of combat capability to the evolving submarine force. Now a new combat system would be developed every 2 years using the latest COTS technology, and the entire submarine force would receive the new systems every 6 years. This generational leap in submarine evolution represents Submarine Warfare 2.0, the digitization of submarine combat and the full adoption of COTS to achieve a persistent acoustic advantage over adversaries.

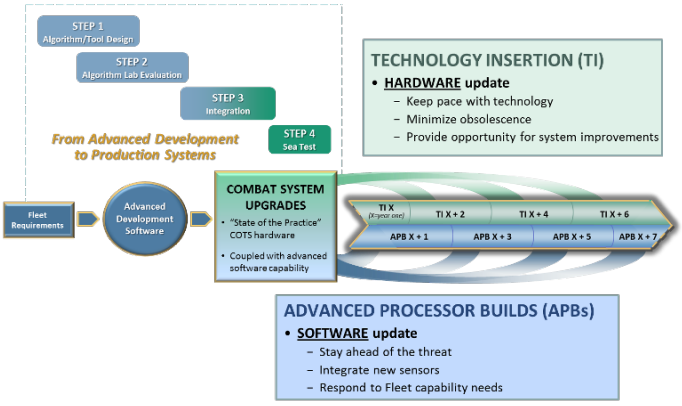

FIGURE 3: TI/APB PROCESS OF ARCI

The Rise of Near Peer Competitors and the Undersea Domain

With the adoption of ARCI, along with the dissolution of the Soviet Union, the submarine force enjoyed over a decade of unmatched superiority at sea. However, with the rise of Near Peer competition, it had to awaken to a new era of adversaries. In the global vacuum created by the Soviet Union's loss of superpower status, new entities have now arisen to be competitive with the United States military. These Near Peer competitors have dramatically

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[8] (Polmar, 2005)

[9] (Paul DeLuca, 2013)

[10] (Zimmerman, 2016)

accelerated their military development and are enjoying the dramatic benefits of the COTS software and hardware technology that is low cost and readily available. The new Near Peer military capabilities that are being employed not only threaten the submarine's survivability but also thrust the submarine into a new warfare gap that has emerged as the leading edge platform in the next conflict.

The United States' Near Peer competitors have developed new capabilities that have challenged the decades old concept of operations (CONOPS) of a SAG as the opening salvo platform in the next conflict. For example, the Anti-Ship Ballistic Missile (ASBM) CSS-5 has an estimated range of over 900 nautical miles (nm)[11] and is armed with a hypersonic warhead that is capable of challenging SAG defensive systems. The CSS-5, as well as many other kinetic and non-kinetic standoff capabilities that have emerged, have essentially pushed the safe operating areas of a SAG beyond its effective offensive range. The SAG's main weapon, the F/A-18 Super Hornet, has an effective combat range of 1,275 nm[12] which would not allow a SAG to launch a strike mission out of range of the CSS-5 and retrieve launch aircraft. This standoff range has now resulted in the submarine, and its stealth capability, once again evolving, now into the front line strike stealth platform capable of employing multiple new payloads.

Near Peer competitors not only have developed kinetic standoff systems that threaten SAG's, but they have also developed new non-kinetic capabilities that threaten the survivability and effectiveness of the submarine. Offensive cyber-attack capabilities are one of the major non-kinetic weapons that threaten the Submarine Force in the way that sonar and cryptology advances in the 1940's did. Look no further than the incursion into the Ukraine in 2015 to see the devastating potential of cyber threats. On December 23rd 2015, coordinated cyber-attacks shut down seven electrical substations in the incursion zone of Ukraine, which cut power to over 250,000 buildings[13]. These capabilities are not limited to civilian industrial equipment, and they represent a substantial threat to any military Information System afloat or on land. A successful attack would cripple the front line platforms in the next conflict leaving all the cutting edge capability useless.

The Submarine Force must once again evolve as the current global environment has seen the growth of Near Peer competition not only in defensive capabilities but also against offensive cyber threats. The submarine is the best current platform to fill the first strike mission gap that has now emerged with the U.S.'s adversaries' impressive standoff capabilities. The American SAG has now been pushed out of range. Therefore, the submarine must fill that gap by employing new multi-mission payloads. The submarine must adopt cyber resiliency to be able to withstand and recover from cyber attacks in order to employ these new critical multi-mission

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[11] (National Air and Space Intelligence Center, 2009)

[12] (Naval Air Systems Command, 2009)

[13] (Electricity Information Sharing and Analysis Center, 2016)

payloads. This may be the most critical evolution the Submarine Force has ever had to adopt. Submarine Warfare 3.0 represents one of the most crucial developments to our nation's defense before Near Peer competition overcomes our naval superiority.

Submarine Warfare 3.0 and Beyond: The New Era in Submarine Warfare

The current global environment has brought unprecedented challenges, and a new era in Submarine Warfare is essential to maintaining freedom of the sea and security of our homeland. The explosion of foreign military capability has now increased the standoff ranges of our Naval assets beyond safe effective range. Furthermore, readily accessible and low cost cyber capabilities enable not just Near Peer competitors but also non state actors to be able to inflict serious degrading attacks against American assets. This combination of threats and dynamic environments will require the submarine to adapt to a new type of warfare with rapid integration of diverse payloads and cyber resiliency. The generational leap of ARCI accelerated the Submarine's combat capabilities to the fleet and now must be iterated on again to add speed, security and versatility to the undersea warfare domain. This combination of capabilities will be the third major evolution of the submarine's mission, Submarine Warfare 3.0.

New Payloads and New Capabilities, Faster and Employed Everywhere

The undersea warfare domain is now the premier battleground of the next conflict. This will put a new role on the submarine to employ a host of payloads, from kinetic payloads such as missiles, to undersea weapons like ADCAP torpedoes, to a host of unmanned systems. With the SAG unable to safely employ numerous capabilities during the initial stages of a conflict, the submarine, which has traditionally only employed Tomahawk Land Attack Missiles (TLAMs) and Advanced Capability Heavyweight torpedoes (ADCAPs), must now fill this warfare gap. New payloads will be required in order to deliver ISR, Electronic Warfare (EW), and new kinetic payloads that the SAG would traditionally employ. An essential element to delivering these capabilities is the

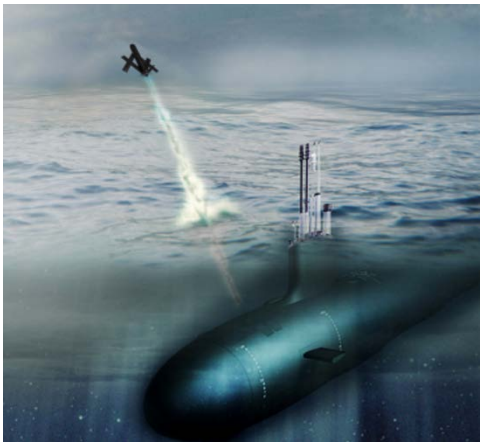

FIGURE 5: BLACKWING UAV

employment of Unmanned Systems such as Unmanned Aerial Vehicles (UAVs)[14] and Unmanned Underwater Vehicles (UUVs). UAVs and UUVs will represent a whole new front in the undersea domain. They are able to operate autonomously in conjunction with manned assets to represent a key force multiplier. Unmanned Vehicles (UxVs) also offer tremendous versatility because they are able to employ different payloads of their own and operate independently. These new payloads will bring with them an order of magnitude more integration complexity than traditional undersea weapon systems. UxVs will require extensive mission planning capabilities and high bandwidth data communications in order to execute mission sets. These complex new payloads are also rapidly evolving, which means updates will be required much more frequently than ARCI has been able to accomplish.

Submarine Warfare 3.0 must now be able to accelerate deliveries of capability and be able to immediately update the entire fleet once the capability or payload integration is completed. The ARCI process is structured to deliver a new combat capability every two years, and within 6 years the new capability and/or payload will be installed on every submarine in the fleet. ARCI was cutting edge for its time, but it is far too slow of a process in the modern era of warfare. The new architecture for submerged platforms must be able to rapidly accept new certified combat capabilities. That means once a capability is completed and ready to operate, the platforms cannot wait potentially years to receive them. This will require new architectures to support micro-services, expandable hardware, common data standards[15] to host new capabilities, and rapid certification technology such as automated testing. Entirely new processes for the Department of Defense (DoD), such as Agile Development[16] and Platform as a Service (PaaS) software must now be transitioned into the entire undersea enterprise. Naval Sea Systems Command (NAVSEA) has proven how quickly combat capability can be delivered by updating the entire SSBN fleet within 14 months[17]. This rapid deployment ability must now be expanded, and new versatile architectures, processes, and culture must now be implemented. Technology development has now reached such a breakneck speed that if the Submarine Force does not adopt a more rapid process, the Near Peer competition will continue to challenge and potentially surpass our deployed undersea capabilities.

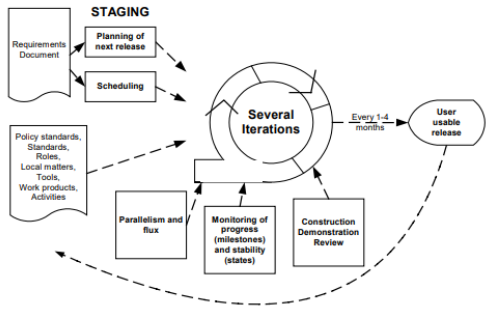

FIGURE 6: AGILE DEVELOPMENT

[14] (LaGrone, 2016)

[15] (CHIPS Magazine, 2018)

[16] (Pekka Abrahamsson, 2002)

[17] (Zimmerman, 2016)

Cyber Resiliency to cope with the Cyber Onslaught

A Cyber Resilient submarine platform is an essential element of Submarine Warfare 3.0 so the platform can remain in the fight while enduring the inevitable barrage of cyber-attacks. The demand to adopt new more capable Information Technology (IT) also poses a significant threat by relying on more and more software and hardware, which increases the attack vectors for Cyber intrusions. Offensive cyber-attack capabilities have proliferated to such a high degree that crippling malware such as Stuxnet[18] may reside dormant in software systems undetected for long periods of time only to be activated at crucial moments. Malware has become such a low cost offensive weapon that even non-state actors have been able to utilize them. This presents a daunting challenge for Submarine Warfare 3.0, as this unpredictable and inevitable threat has the potential to devastate any platform at critical battle altering moments.

The new submarine architecture must be designed to expect cyber intrusions to occur and be able to respond and recover rapidly. As vigilant as DoD cyber protections are, it is nearly impossible to entirely prevent vulnerabilities in IT systems today. Therefor the combat architecture must have built in segregation of capabilities and payloads from each other. This would contain any vulnerability that emerges to the affected system like a quarantine. Using technology such as Virtual Machines (VMs), a software application experiencing a cyber-event would be contained and recovered rapidly from a known good state. This allows an affected platform to still remain combat effective and give it the resiliency to recover degraded or lost capability in time to remain in the fight. Cyber Resiliency will be the critical defensive technology of Submarine Warfare 3.0 and is a crucial capability for dominance of the undersea domain.

Conclusion

The submarine Force has seen several generational changes over the last century and now faces its next evolution into a resilient front line strike platform capable of employing a diverse array of payloads rapidly. The conventional warfare stakes have never been higher as new Near Peer competition has employed impressive military capabilities that must be overcome. Standoff ranges have never been higher pushing SAGs and other traditional assets out of safe effective range for effective

FIGURE 7: COLUMBIA CLASS SSBN

[18] (Kushner, 2013)

missions. This has created a warfare gap that has fallen to the undersea domain, the domain of the Submarine. The submarine force has responded to such challenges over many generations, from the World War I and II anti-ship combat era to the acoustic superiority race during the Cold War, and now against powerful Near Peer competition.

Submarine Warfare 3.0 is the new generation of undersea combat, and it will require flexible and rapid employment of new capabilities and payloads, combined with cyber resiliency to maintain operations. The threat of cyber attack is dynamic and multi-vectored, and cyber resiliency will be the key defensive capability. It is as important today as acoustic signatures have been in the past. The new architecture must assume an intrusion will occur and must have the capability to rapidly detect, remedy, and recover the systems. The submarine force must also evolve its culture, processes, and architectures to be able to employ capability faster than ARCI to the entirety of the submarine fleet immediately. These are heavy challenges. But the submarine force has proven generation after generation that it is ready to respond and evolve to meet the warfare gaps of the day.

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